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THE INDEPENDENT VERIFICATION, VALIDATION, AND ACCREDITATION PROCESS AS APPLIED TO EXTENDED AIR DEFENSE TESTBED

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Abstract

This paper discusses the Independent Verification, Validation and Accreditation Process as applied to Extended Air Defense Testbed (EADTB). The process covers logical verification and code verification techniques and both structural validation and output validation techniques. Specific examples from EADTB are included to demonstrate application of the techniques.

1.0 Background

The focus of the EADTB design is to support analyses that encompass all aspects of the joint service extended air defense issues for Theater, Air and Missile Defense (TAMD) with emphasis on Battle Management Command, Control, Communications and Computer (BMC4I) architecture and operations. The EADTB provides common tools for supporting analyses of: present and evolving air threat, present air and space based defense effectiveness and limitations, and future conceptual defenses involving operational and/or technological improvements. The EADTB is used by materiel developers to define and evaluate system concepts, by combat developers to develop doctrine and tactics, by the Tester and Evaluator (T&E) to support testing, and by operational commanders for staff training and battle planning (such as EADTB's support of Roving Sands).

The EADTB provides for the simulation of scenarios ranging from few-on-few to theater level (and extendable to NMD levels) using a common set of tools and algorithms. EADTB is being designed to be compliant with the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA) rules. The EADTB represents land, sea, air, and space systems in active defense, passive defense, attack operations, and BM/C4I as well as the environment, other targets, and the interactions with other forces and missions.

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EADTB models are composed of user provided data feeding generic algorithms (with modifiable rulesets to govern the control structure) which can be configured into models or Specific System Representations (SSRs). These representations along with an experiment preparation system form the basis for a library system enabling analyses to be constructed, calibrated, and varied more rapidly.

2.0 Executive Summary

This paper presents a methodology for verification, validation and accreditation of models and simulations. This paper contains information for conducting a complete verification, validation and accreditation study, from the problem definition stage to the documentation of the results in a comprehensive final report. Attention to detail is paramount throughout the VV&A effort to ensure that the final product meets the needs of the customer or application sponsor.

This document does not discuss every possible technique used in VV&A work but rather, presents generic processes used by Quality Research on the EADTB. This process can be expanded as programs mature and additional case studies become available. For details about VV&A techniques not mentioned herein, the reader is referred to the Department of Defense (DoD) Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide.

3.0 Key Terms

Verification

Verification is the process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specifications. (Is the simulation what I intended?)

There are two basic types of verification. Logical verification ensures that the basic equations, algorithms and logic flow are correct. Code verification ensures that these representations have been correctly implemented in the code.

Verification also evaluates the extent to which the model or simulation has been developed using sound and established software engineering techniques. Verification is applied at each stage to ensure that the products of that stage accurately implement the specifications from the previous stage.

Validation

Validation is the process of determining the degree to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model or simulation.

Validation is viewed from multiple perspectives, the most important of which include: 1) structure and depth sufficient to adequately represent the real world for a given application, 2) behavior, including the ability to predict system performance, and 3) information conveyance. Validation is ultimately accomplished by testing and evaluating the results of exercising the systems and simulations in realistic applications

Accreditation

Accreditation is an official determination that the simulation as a whole or any one of its components when examined independently is acceptable for use for a specific purpose. (Should my organization endorse this simulation?)

Accreditation is a decision that is based on several different factors, including verification and validation.

4.0 VV&A Activities

The VV&A activities for EADTB are closely tied to the life-cycle of the software development process for EADTB. Figure 4.0-1 shows the EADTB VV&A Process Model. VV&A activities are ongoing processes throughout the life cycle of the EADTB. VV&A activities are accomplished at each life cycle stage of the EADTB.

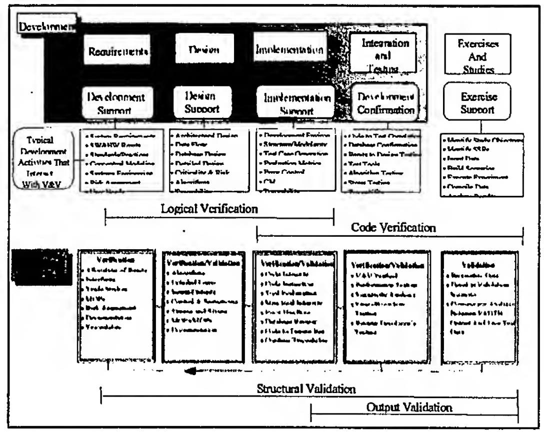


Figure 4.0-1 EADTB VV&A PROCESS MODEL

The VV&A Process for EADTB is; (1) compliant with evolving guidance (multi-service and DoD) and state of practice, (2) tailored to the circumstances of the EADTB development process, simulation characteristics and intended uses and, (3) pro-active in building the audit trail of evidence necessary and sufficient for confidence in EADTB results and outputs.

5.0 Verification Methods

The general process model shown in Figure 4.0-1 used to perform VV&A has been implemented by the EADTB VV&A team. Figure 5.0-1 shows how the EADTB VV&A team employs the process to perform verification.

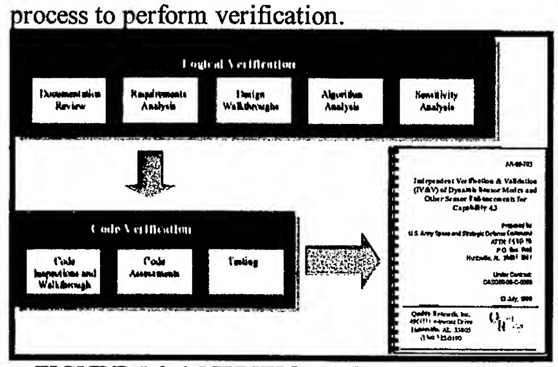


FIGURE 5.0-1 VERIFICATION PROCESS MODEL

The following sections show how the VV&A team implements this process model for the EADTB.

5.1 Requirements Analysis

Requirements analysis involves verifying complete, consistent and accurate requirements, reviewing requirements documentation, verifying testability of requirements and establishing traceability of all requirements to and from a source.

Requirements traceability helps to ensure that all requirements have a well-defined source and purpose. Traceability reduces the potential for modification of requirements. In addition, setting up traceability provides an additional check on the consistency and accuracy of the requirements.

Requirements traceability analysis is performed to track and correlate requirements specifications from the technical requirements documentation through the implementation phase of the software development life-cycle. By tracking each system level requirement through each development phase, requirements traceability analysis provides an assessment of the completeness of the development at each phase.

The EADTB VV&A team reviews and analyzes all EADTB software requirements documentation. This review identifies:

- critical requirements
- design and test product items in critical requirements threads
- significant omissions, inconsistencies, ambiguities and errors in critical design and test product items
- critical requirements based on performance, functionality, error recovery, sizing and timing constraints or other criteria
- CSUs, CSCs, CSCIs, interfaces, interface messages, test cases and test procedures associated with critical requirements

The items identified from the documentation reviews lead to the determination that:

- the requirements documentation adheres to the applicable standards
- the system fits correctly within its global context and all external originating requirements are adequately incorporated or otherwise accommodated
- each requirement is valid, adequate, correct and unambiguous
- all requirements correctly trace to all appropriate levels of specifications and that the references are re-verified whenever a change occurs.

The EADTB VV&A team developed a tool to perform requirements analysis. The tool consists of a database that contains all of the software requirements associated with the EADTB framework. Keyword searches allow the tester to easily review the database for any requirement associated with the test. The tester also has the ability to review requirements associated with the unit under test and generate reports containing these requirements. Once the requirements are tested, the database provides a repository where EADTB's adherence to the requirements may be tracked. An area is provided to describe any software change requests or trouble reports associated with the tested requirement. All the data is recorded for retrieval in a variety of reports and is related to the test name for archival purposes. Figure 5.1-1 shows the main testing table used to track requirements and software trouble reports for EADTB.

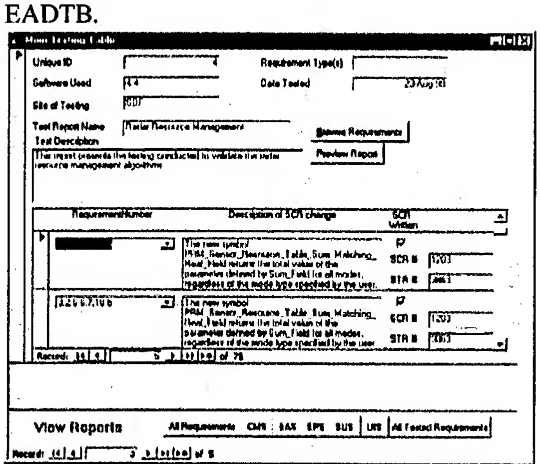


Figure 5.1-1 VV&A Testing Database

5.2 Algorithm Analysis

An in-depth analysis is performed on the EADTB algorithms to verify that each major algorithm is mathematically correct and consistent with established mathematical practices. This involves rigorous verification of the mathematics of an algorithm to ensure that the equations are derived correctly and that there are no errors in the expressions.

Algorithm analysis must be a part of logical verification, code verification and testing. The

initial analysis of the algorithms occurs during documentation reviews. This includes the mathematical analysis mentioned above and is a crucial part of logical verification. Figure 5.2-1 shows the approach to algorithm analysis followed by the EADTB VV&A team.

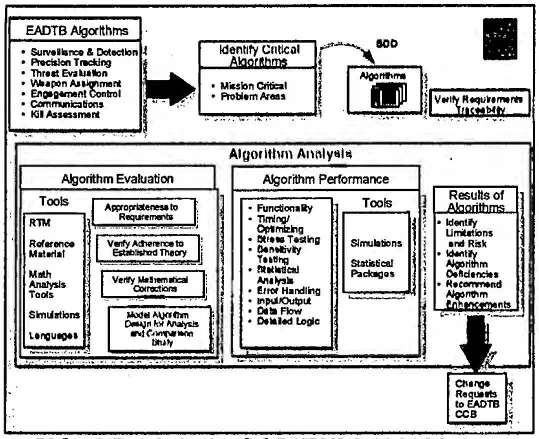


FIGURE 5.2-1 ALGORITHM ANALYSIS

Algorithm evaluation is a crucial part of logical verification. The algorithms are evaluated during documentation reviews to ensure that the appropriate algorithm is provided for each of the requirements. Alternative algorithms may be suggested to the developer at this point. Each of the major algorithms is analyzed for adherence to established mathematical and physical theory. The major equations in the algorithms are derived from first principles to establish correctness. Any errors found in the derivations of the algorithms are presented to the developer for correction before implementation. The mathematical expressions within the algorithms are verified to be correct and free from errors. Mathematical analysis tools are used by the VV&A team for this purpose. The algorithms may be modeled in a suitable simulation or stand-alone for analysis and comparison when appropriate.

Sensitivity Analysis

Sensitivity analyses are performed to ensure that EADTB is reacting to varied inputs in an expected and predictable manner. Input data are systematically varied to test the reaction of the simulation to changes. Extreme and boundary layer testing is performed to determine reaction of EADTB to stressing conditions. Sensitivity analysis facilitates the verification process by highlighting the effects of input data changes on the functional outputs of the code. An EADTB specific example follows which shows the results of a sensitivity analysis performed within a tracking function.

Effect of Process Noise on Tracking

Within the ruleset call to the filtering algorithm, the user may specify a process noise value as one of the arguments of the hard-coded algorithm. This value is actually the sigma acceleration used to build the process noise covariance matrix. The process noise covariance plays an important role in the successful tracking of an object. The process noise is an impulse noise on acceleration. The filter will trust the extrapolation model believing it to be a good model of the target dynamics, if the process noise is low. The filter will believe the sensor measurement if the process noise is high. It is necessary to choose this value carefully. If the process noise is set too low, the filter becomes unresponsive to the sensor measurement. If the process noise is set too high, it may cause divergence.

It is possible to define a high value for the process noise and maintain a track on a maneuvering air-breathing threat, ABT. Even though the kinematic model is a constant velocity model, because of the high process noise the filter will trust the sensor measurement more than the kinematic model and it will weight the estimate accordingly.

A scenario was created to stress the ability to track a maneuvering aircraft with a constant velocity Kalman filter. The process noise argument in the call statement to the hard-coded algorithm for filtering an ABT state was varied on sequential runs. The first set of runs tested the ability to track the maneuvering target with a low process noise. The second set of runs tested the ability to track the maneuvering target with a high process noise.

It was expected that the first set of runs would produce much larger track errors or even losses of track because of the inability to track during maneuver. The high process noise in the second set of runs would compensate for the acceleration within the filter to allow it to continue tracking the target even when it was in maneuver.

Figure 5.3-1 shows the history trail or true position and the perception trails as seen by the

rear radar for a maneuvering target using low process noise covariance. The result is that the target is not tracked as well in maneuver as it is in the constant velocity legs of the waypoint set. The perception trails are seen diverging from the actual position. This filter believes that the model provides good estimates of the target's position. Therefore, when the target begins to maneuver, the filter expects that the target will be continuing on its constant velocity heading.

If a high process noise covariance is implemented within the filter, the measurement from the sensor becomes much more important. The radar is better able to track the target with its continual updates from the radar and because the filter believes the sensor measurements more than the model of the target dynamics. Figure 5.3-4 shows that the perception trail and the history trail differ only slightly.

EADTB provides the ability through ruleset interaction to change the process noise covariance matrix and obtain different tracking characteristics. A comparison of Figure 5.3-2 and 5.3-5 shows that the actual position error is greatly diminished when the process noise covariance matrix is increased. Similarly the actual velocity error shown in Figures 5.3-3 and 5.3-6 illustrates that the high process noise covariance matrix allows for better actual velocity track errors of the maneuvering target.

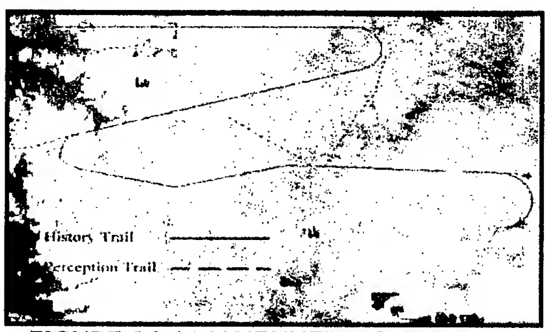


FIGURE 5.3-1 MANEUVERING TARGET TRACKED WITH LOW PROCESS NOISE INPUT

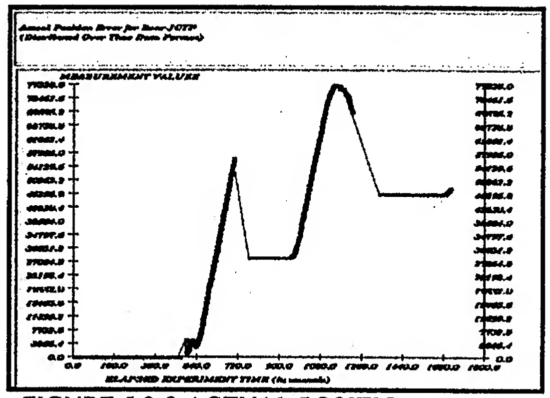


FIGURE 5.3-2 ACTUAL POSITION ERROR FOR HIGH MANEUVERING, LOW PROCESS NOISE TARGET TRACK

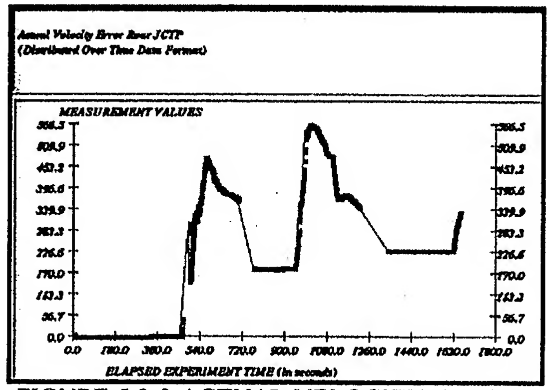


FIGURE 5.3-3 ACTUAL VELOCITY ERROR FOR HIGH MANEUVERING, LOW PROCESS NOISE TARGET TRACK

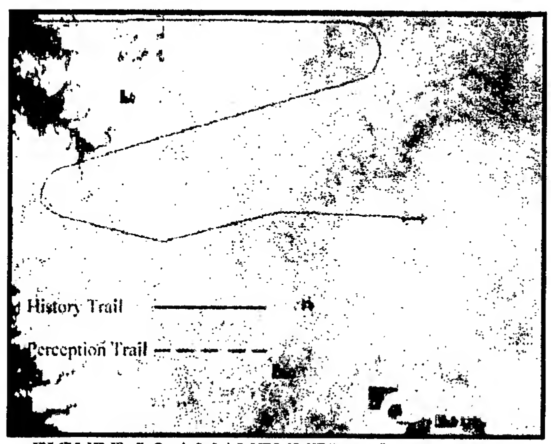


FIGURE 5.3-4 MANEUVERING TARGET TRACKED WITH HIGH PROCESS NOISE INPUT

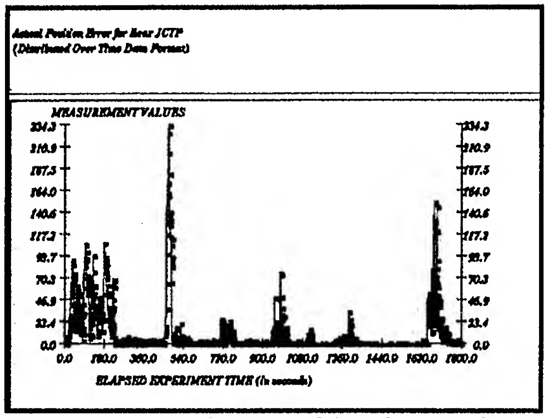


FIGURE 5.3-5 ACTUAL POSITION ERROR FOR HIGH MANEUVERING, HIGH PROCESS NOISE TARGET TRACK

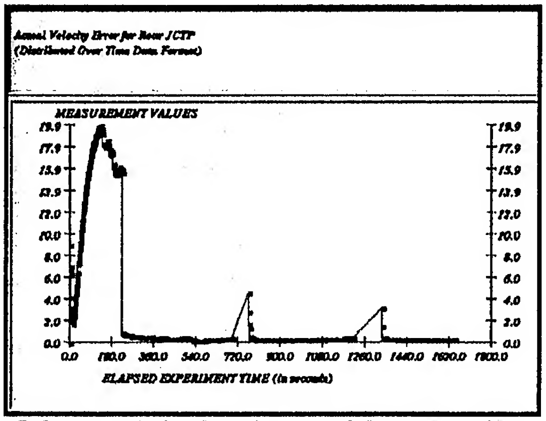


FIGURE 5.3-6 ACTUAL VELOCITY ERROR FOR HIGH MANEUVERING, HIGH PROCESS NOISE TARGET TRACK

5.4 Code Assessments, Code Inspections and Walk-Throughs

Code Assessments, code inspections and walk-throughs are performed by the EADTB VV&A team to determine if the algorithms are implemented properly within the code. Code inspections ensure consistency, correctness and completeness in the implementation.

Within EADTB, code inspections are conducted primarily using the code debugger tool. Code debugging allows the tester to examine the code while stepping line-by-line through the algorithms of interest. Output may be written to the screen for visual inspection or written to a log file for future examination of the data. Discrepancies between accepted equations and algorithms and the implemented code are reported.

Code assessments are used to assess the complexity, adherance to coding standards and recommended practices, imbedded faults, and structural errors. Any inconsistencies are identified between the Program Notebook (PNB) and the code. The EADTB VV&A team uses code assessments to evaluate threads through calling sequences for selected events as shown in Figure 5.4-1.

```
CMS_SN_PCM_Controls.Event_Dispatcher

Execute_Start_Search

CMS_SN_MDL_Radar.Start_Search

CMS_SN_DT_Radar_Control_Mode.Long_
Term_Cost_Of

CMS_SN_PCM_Commands.Active_Scan_
Complete

Compute_Next_Activation_Time

CMS_SN_PCM_Events_Manager.Schedule
("Active_Scan_Complete")
```

FIGURE 5.4-1 CALL SEQUENCES USED WHEN PERFORMING CODE ASSESSMENTS

The call threads enable the tester to determine which coding packages are affected by errors in implementation of the algorithms. The code assessment helps determine the impact of errors.

Testing

EADTB requires user-defined rulesets to invoke specific symbols which, are in turn, used to stimulate hard-coded algorithms within the ADA code. Testing seeks to construct the necessary test scenario to adequately examine the area of interest. Within EADTB, this requires that the tester prepare system models by defining the necessary input parameters and ruleset calls. The tester must define the gameboard to be used, deploy the scenario elements, build message data tables and network connectivity data sets, resolve aliases and identify measures of effectiveness (MOEs) and measures of performance (MOPs) for output.

Once developed, the scenario is executed within an experiment. Data for a run is archived in trace logs, error logs and recorded data items for future examination. A graphical user interface is

available to inspect the operations of a scenario. Radar detection/tracking lines, radar modes, message communications, platform movement, perception lines, history trails and entity states may be examined by inspection.
MOEs and MOPs are recorded through an analysis tool. This tool allows for playback of the scenario as well as examination of the recorded data items. These may be exported to for further analysis using spreadsheets or parsing codes. An example follows of a test that was performed to test the number of hops to a gateway requirement within EADTB.

Number of Hops to Gateway

A gateway component is a component that is designated as a message translator from one network to another network. The use of the gateway is utilized when a message is set to transmit to a Comm component on the other network. The design of the networks for a gateway is shown in Figure 5.5-1 below.

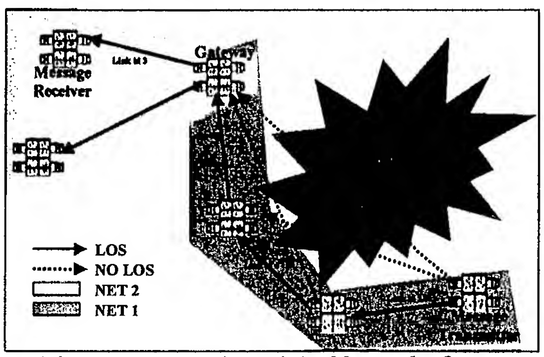


Figure 5.5-1 Design of the Networks for a Gateway

EADTB states that Comm shall determine the maximum number of hops for retransmission on the new network based on the following parameters: Number of hops that the message used to get to the Gateway and maximum number of hops for the original message. The Figure 5.5-1 illustrates the use of a gateway exactly four hops away from the message transmitter on the sending network. The message is sent to the ScenEl on the receiving network that has line of sight with the gateway. As Figure 5.5-1 illustrates, the message will take a minimum of four hops to get to the destination. The Comms Link Status RCD shows the various link connectivity status enumerations for the ScenEls per network. The valid paths can be traced from the Comms Link Status RCD as shown in Table 5.5-1 below.

Table 5.5-1 Comms Link Status RCD

Status Time	Link ID	Network ID	Source ScenEl Comm Comp ID	Destination ScenEl Comm Comp ID	Connectivity Status
0.00E+00	1	1	339126	339123	OPERABLE
0.00E+00	2	1	339123	339126	OPERABLE
0.00E+00	3	1	339228	339123	OPERABLE
0.00E+00	4	1	339123	339228	OPERABLE
0.00E+00	5	1	339228	339126	OPERABLE
0.00E+00	6	1	339126	339228	OPERABLE
0.00E+00	1	2	338794	338791	OPERABLE
0.00E+00	2	2	338791	338794	OPERABLE
0.00E+00	3	2	339211	338791	OPERABLE
0.00E+00	4	2	338791	339211	OPERABLE
0.00E+00	5	2	339227	338791	NON_LOS
0.00E+00	6	2	338791	339227	NON_LOS
0.00E+00	7	2	339211	338794	NON_LOS
0.00E+00	8	2	338794	339211	NON_LOS
0.00E+00	9	2	339227	338794	NON_LOS
0.00E+00	10	2	338794	339227	NON_LOS
0.00E+00	11	2	339227	339211	OPERABLE
0.00E+00	12	2	339211	339227	OPERABLE

6.0 Validation Methods

According to DoD 5000.59, validation is the rigorous and structured process of determining the extent to which modeling and simulation accurately represents the intended "real world" phenomena from the perspective of the intended use of the model and simulation. Validation has two main components: structural validation and output validation (also called conceptual model validation and results validation). Structural validation focuses on the internal portion of the modeling and simulation which includes examination of modeling and simulation assumptions and review of the modeling and simulation architecture and algorithms in the context of their intended use. Output validation answers questions on how well the simulation results compare with the perceived real world.

The Validation Process used for EADTB is illustrated in Figure 6.0-1 and is comprised of

four main tasks: (1) problem definition, (2) structural validation, (3) output validation, and (4) preparation of a validation report. These elements are discussed in the following sections.

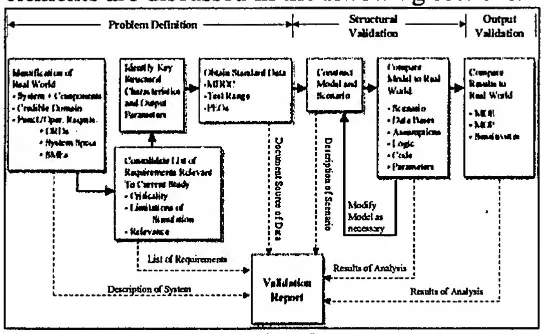


FIGURE 6.0-1 VALIDATION PROCESS FOR EADTB

6.1 Problem Definition

The validation process begins with a clear and unambiguous statement or definition of the problem. A good definition of the problem makes it easier to define its solution requirements. These requirements are the features, characteristics, or functions that are important to the problem and essential to its solution. Two pillars compose the problem definition process. The first is the identification of the real world being modeled. The second is the identification of the key structural characteristics and output parameters that are to be used for the comparisons during the validation process. The procurement of standard data has also been included in the problem definition process because the outcome of the first two steps is a clear understanding of the data input items that are required by the simulation.

6.1.2 Identification of the Real World

Identification of the real world involves definition of the system(s) that will be modeled and to what level of fidelity (i.e. terrain, weather, environment, features). Validation is the comparison of the M&S behavior and results to data obtained from another credible domain that is either believed to be the real world, has been proven to closely approximate the real world, or is from a source that is recognized as expert on the relevant characteristics of the real world. Some real world data sources include the following. Each of these real worlds has inherent drawbacks and limitations that can make or break the validity of a simulation.

- Subject matter experts (SME) or other recognized individuals in the field of inquiry. Face validation enables the "experts" to compare the simulation structure and output to their estimation of the real world.
- Scientific theory and accepted algorithms that define the ranges of acceptable behavior in response to given inputs.
- Laboratory test, developmental test, system operational test or other engineering data that provide a set of empirical data points that correspond to specifically identified input data.
- Training facility measurements and live fire training and test results for comparison.
- Comparison with historical values. This includes measurements of the phenomena of war or historical results.
- Touchstone modeling and simulation such as previously and separately validated models and simulations.

The VV&A team participated in a validation of the ballistic missiles modeled within EADTB. The U.S. Army Space and Missile Defense Command (SMDC) has developed a family of targets that is representative of a variety of threats to allow a comprehensive evaluation of theater missile defense system capabilities. Models of these targets and other ballistic missile systems were constructed in the Extended Air Defense Testbed (EADTB). These models were validated to ensure they are an accurate representation of the real system. The purpose of the validation effort was to provide a quantitative assessment of how well the models represent the real systems. The following are the targets and other ballistic missile systems which were constructed and validated in EADTB:

- MBRV-1 Single Stage and Two Stage Configurations
- Two Stage Hera Block II THAAD Unitary Target
- Two Stage Hera Block II Patriot Unitary Target
- Multi-Service Launch System (MSLS) Target
- Aries

- Lance GM-52C Missile

The purpose of the validation effort was to construct models of these ballistic missile systems and then compare the models and their behavior to the real systems and their behavior. There are two distinct methods for representing ballistic trajectories in EADTB: 1) EADTB internally-generated trajectories, and 2) imported pre-planned threat tape trajectories. All of the testing was conducted using the EADTB internally generated trajectories. Ballistic Missile Move (BMM) is a collection of algorithms within EADTB which provide a variety of ballistic motion options. Each ballistic missile scenario element (ScenEl) has input parameters which are established by an EADTB user, stored in a relational database, and retrieved and loaded into BMM at the start of an experiment. These parameters can be broken into three types:

a. Specific System Representation (SSR) parameters which specify the performance capabilities of ballistic missiles of a given type.

b. Instance parameters which are unique for a given ballistic missile scenel and do not change throughout the experiment.

c. Dynamic parameters which are unique for a given ballistic missile scenel, are initialized by the user, and can change as the experiment is executed.

The values for these parameters were derived from missile performance and flight test data provided by the Targets Office for each of the systems listed above.

Key Structural Characteristics and Output Parameters

Identification of key structural characteristics and output parameters involves determining the categories that are of interest for the intended use of the model or simulation. Examples of key structural characteristics are mass, dimensions, thrust, burn rates, available power, location, terrain, weather, and backgrounds. Key output parameters are used to assess the validity of the model. Examples of these are flight trajectory (range, apogee, time of flight), number of missiles launched, number of missiles killed, and message error rates. These parameters may be found in various MOEs, MOPs, and Recorded Data Items (RCDs) and are illustrated in Figure 6.1.3-1.

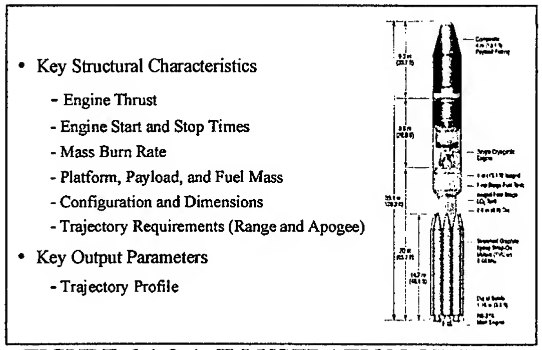


FIGURE 6.1.3-1 ILLUSTRATION OF KEY STRUCTURAL CHARACTERISTICS AND OUTPUT PARAMETERS

Emphasis in different areas dictates that different items are of importance. The following categories of models and simulations illustrate this difference:

- Research and Development. These simulations require a high level of fidelity. Validation emphasizes completeness and balance of algorithms. Items of importance include the portrayal of the subsystems, components and system parameters, physics phenomena, and interactions with the environment.
- Education and Training. These simulations provide emphasis on education and training of soldiers. As such, validation items will tend to center around human interactions and interfaces and the quality of after action reviews.
- Analysis. These simulations support the analysis of weapon system effectiveness, new tactics and doctrine, force structure studies, and budget assessments. Validation centers on issues of algorithm's robustness, completeness and balance.

Data Requests

Once the real world system has been defined and the key structural characteristics and output parameters have been identified, the analyst should have a clear understanding of the data input items that are required by the model. These items will include both data used to construct the model as well as data used to evaluate the output. The analyst is responsible for obtaining standard data for this purpose. There is a distinction in terminology here when referring to data that have been verified, validated, and certified. Verified data are useable by the M&S code. Validated data have been reviewed for their reasonableness and conformance to real world when available. Certified data come from approved data sources. Prior to obtaining any data, the analyst shall confirm whether or not certified data are required.

1. Data Certification: If the customer or application sponsor requires certified data from a data supplier, then the analyst must request a new set of certified data for each application of the M&S. Threat data must be reviewed and approved by the appropriate intelligence agency prior to each use to determine whether changes have occurred that require updating. Certification establishes that the data are suitable for a specific use. Once the certified data items are received, they must be verified and validated.

2. Data Verification: Data verification is the process of ensuring that primary source data to be used in the validation effort are converted to the correct input formats and units of measure and have values within the allowable range as specified in the design of the M&S. This ensures that the input and output data are in the proper format to be manipulated by the M&S. Data verification establishes that the data produced conform to the specification.

3. Data Validation: Data validation is the comparison of input data to the corresponding known real world or best estimate values. Data validation is typically performed by the M&S user to ensure that the data utilized in the M&S are appropriate and reasonable for its usage.

Table 6.1.4-1 represents some of the data that was available for the systems of interest to the TBM validation study.

Table 6.1.4-1

Sample Single Stage Missile Parameters

	600 km Long Range Ballistic Trajectory	660 km Unballasted Max Range Trajectory	LUT-1 Trajectory
Booster Engine	SR-19	SR-19	SR-19
Average Thrust (Newtons)	247,597	247,597	247,597
Engine Start Time (seconds)	0.0	0.0	0.0
Engine Stop Time (seconds)	65.0	65.0	65.0
Mass Burn Rate (kg/sec)	95.97	95.97	95.97
Specific Impulse (seconds)	263.26	263.26	263.26
Platform Mass (kg)	1579.0	1579.0	1579.0
Ballast Mass (kg)	771.0	0.0 (unballasted)	771.0
Fuel Mass (kg)	6238.0	6238.0	6238.0
Payload Mass (kg)	581.0	581.0	581.0
Total Launch Mass (kg)	9169.0	8398.0	9169.0
Range (km)	600.0	660.0	320.0
Apogee (km)	186.0	191.0	236.0
Aero Reference Area (m^2)	1.973	1.973	1.973

Preparation of Test Scenario and Structural Validation

Construct Scenario

The data collected in section 6.1.4 are used to construct a scenario designed to represent the real world as closely as possible. The validation study may call for using specific models or simulations as they are, modifying existing models and simulations, or developing new models or simulations. The primary steps for preparing an experiment in EADTB are discussed in the following section.

6.2.1.1 EADTB

EADTB is a high detail/fidelity simulation system for missile warfare analysis. The key steps associated with the experiment preparation process in EADTB are shown in Table 6.2.1-1. The analyst defines inputs available, outputs required, accuracy required, and any sensitivities (output-to-input) that must be correctly represented. The key output parameters which will be used to assess the validity of the model are often found in various MOEs, MOPs, and Recorded Data Items (RCDs). The analyst must specify which of these parameters should be recorded.

Table 6.2.1.1-1 Key Steps of Experiment Preparation in EADTB

Step	Description
Prepare System Models	Select existing models from the master library or develop new ones. The model structure is normally divided into the four functional modules: Thinker, Platform, Sense, and Communicate.
Define Gameboard	Select from an existing gameboard definition or develop a new one. Gameboard definition requires specification of location, terrain, weather, and backgrounds.
Laydown ScenEls	The process of defining a simulated entity (referred to as a ScenEl) includes deploying a copy of a system model onto the gameboard, initializing dynamic variables, setting any static variables, defining any links, and resolving all the external aliases.
Build Message Data Table	A message data table defines communication protocols and data fields. An existing table can be used or a new table can be defined.
Build Connectivity Data Set	The connectivity data set defines communication links between nodes in networks and gateways between networks.
Resolve Remaining Aliases	The model code uses surrogate symbols for other interacting entities that must be specified (or resolved) when a ScenEl is placed on the gameboard. These surrogates, referred to as aliases, are partially resolved by the connectivity data set. EADTB prompts the user for any other unresolved aliases during experiment preparation.
Specify MOEs and MOPs	The user can select from a set of MOEs and MOPs that can be recorded during execution. In addition, the user can specify which internal dynamic variables (e.g. state variables) should be recorded.
Specify Console Configuration	The user specifies the configuration of the terminals for observers / participants in interactive runs.
Set Execution Options	EADTB offers a number of execution options including interactive, batch, and real-time. Experiment preparation includes the input of experiment start and stop times, preselected pause points, and numbers of runs in a Monte Carlo set.

A scenario was constructed in EADTB for validating the TBM model as shown in Figure 6.2.1.1-1. The scenario elements were constructed. Desired apogee and target range are identified at the instance level. EADTB internally generates the trajectory using a 3DOF Model. Measures of performance were recorded. These included the following:

1. Altitude vs. Time
2. Altitude vs Downrange
3. Velocity vs Time

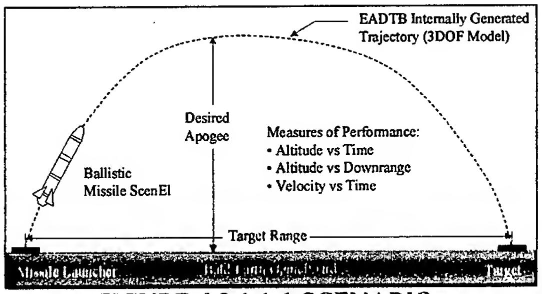


FIGURE 6.2.1.1-1 SCENARIO CONSTRUCTION FOR TBM VALIDATION IN EADTB

Structural Validation

Structural validation focuses upon the internal portion of the modeling and simulation which includes examination of modeling and simulation assumptions and review of the modeling and simulation architecture and algorithms in the context of their intended use. The DoD VV&A Recommended Practices Guide calls this stage "conceptual model validation" and defines it as the determination (usually by a group of subject matter experts) that the assumptions underlying the proposed conceptual model are correct and that the proposed simulation design elements and structure (i.e. the simulation's functions, their interactions, and outputs) likely will lead to results realistic enough to meet the requirements of the application. Conceptual model validation ensures that the proposed conceptual model (and its resultant design) satisfies the fidelity, accuracy, or credibility requirements imposed by the specifics of the problem. Structural validation contains answers to the following questions.

- Is the simulation sensitive to the proper input data items; such as, does the difference between two sets of simulation results reflect a believable result given the variation in the input data sets? Is the simulation credible?
- Do the individual pieces such as the functional areas and system units of the simulation adequately represent their counterparts in the "real world"? (Comparison of models and simulations to real systems)
- Is the model and simulation complete and are the functions adequately modeled? (Completeness and adequacy of actual system functions) This may involve inspection of design documents to compare equation and algorithm methodology to outside documentation. Comparison to other accepted methodology is also possible.
- Is there a balance of representation across all model and simulation components? Are elements of the simulation represented at different levels of fidelity within the simulation itself? What impact does this have on other systems within the simulation? What relationships exist between individual elements that require similitude in modeling levels? What aspects do not have to be modeled at as high a level of fidelity without impacting other elements within the simulation? (Consistency of the modeled systems within the scenario)
- Does an adequate and consistent representation of terrain and environment exist across all model and simulation components? (Consistency of terrain and environment across the simulation)

Output Validation

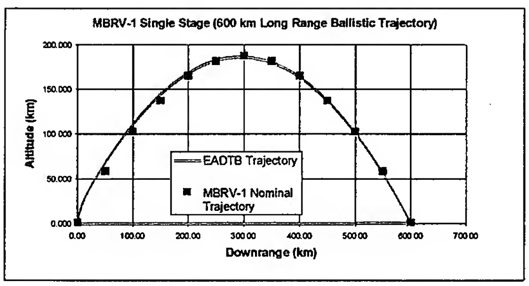
Output validation answers questions on how well the simulation results compare with the perceived real world. The DoD VV&A Recommended Practices Guide calls this stage "results validation." Results validation compares the responses of the simulation with known or expected behavior from the subject it represents to ascertain that those responses are sufficiently accurate for the range of intended uses of the simulation. This process includes comparison of simulation outputs with the results of controlled tests, sensitivity analyses, or expert opinion. One useful approach to output validation is graphical comparison. Output validation contains the answers to the following questions:

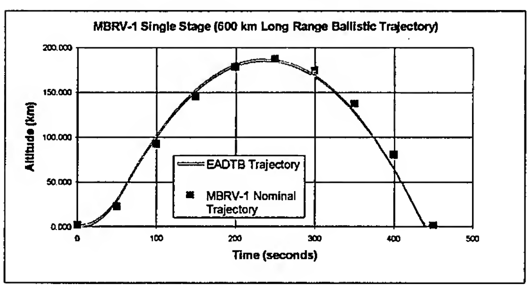
- Does the simulation produce results that are plausible? (Veracity and acceptability of the results)
- Is the output/result reasonable relative to the inputs? Is there mathematical consistency between input data and results? For example, we may expect greater detection range results from raising the power in a radar.
- Does the difference in input produce the expected proportional change in the output? Do changes in data result in anticipated and comparative changes in output?
- How does the model output compare to historical data, test data, laboratory data or

exercise data? Compare simulation to "real world" data. For example, how well does a simulated ballistic missile trajectory correlate with actual flight test data?

Graphical Comparison

Graphical comparison is a subjective, inelegant, and heuristic, yet quite practical approach to output validation. The graphs of values of model variables over time are compared with the graphs of values of system variables to investigate characteristics such as similarities in periodicities, skewness, number and location of inflection points, logarithmic rise and linearity, phase shift, trend lines, and exponential growth constants. The graphs in Figure 6.3.1-1 demonstrate how graphical comparison can be used to evaluate correlation between model variables and system variables.





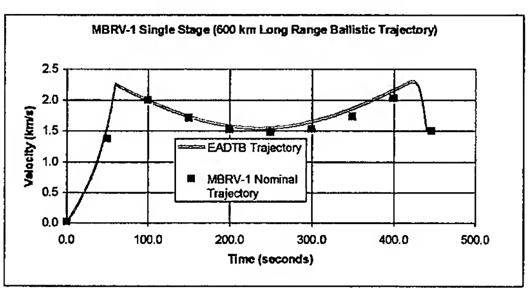


Figure 6.3.1-1 Examples of Graphical Comparisons between Model and System Variables

6.4 Methods of Validation

Procedural and technical approaches that are frequently used in validation are described below. These methods may be used as appropriate to support the validation effort.

- Peer review. A validation approach that involves conducting critical and detailed examinations of internal representations of data inputs, key parameters, and resulting output by personnel who are knowledgeable about modeling the functional areas represented in simulation.
- Independent review. Validation performed by competent, objective reviewers who are independent of the simulation developer. It may consist of examination of the adequacy and completeness of the verification and validation methods already performed by the simulation developer.
- Face validation. The validation process of determining whether a model, on the surface, seems reasonable to personnel who are knowledgeable about the system or phenomena under study.
- Comparison to other models and simulations. This uses results or output from internal algorithms or other simulations already accredited for use in similar applications as part of both structural and output validation. Direct comparison of code, documentation, input data, and results are the primary techniques used.
- Piecewise Validation or functional decomposition. Decomposing the model into functional components is often a great aid in the validation process. Functional area SME for each part of the model and simulation are brought in to examine in detail the documentation, code, and output to determine the validity of each segment of the decomposed model.
- Stress tests and sensitivity analysis. SME validates whether the model and simulation provides proper output responses to inputs for the entire spectrum of valid input data.
- Animation and graphics playback. These techniques allow the analyst to see the simulation's behavior through time.
- Turing tests. These tests ask experts in operation of a system to differentiate between data flow, controls and outputs of the real world system and modeling and simulation results.

The method for achieving the desired level of validation is Model-Test-Model (M-T-M). M-T-M is a method that uses test and evaluation results in an iterative method of successive simulation improvement, with each successive step increasing the overall validity. The M-T-M process is accomplished through the following steps: model the scenario; observe test play; constrain the model to test conditions; compare the measures to observations; adjust the simulation; re-run the model and repeat the cycle as necessary. The basic components of M-T-M are: pretest modeling, measures and test observations comparison, and posttest modeling. These phases are run successively until the desired degree of validation is achieved.

7.0 Accreditation

Accreditation is the official determination by the application sponsor that the capabilities of the model and simulation fit the intended use and that its limitations will not interfere in drawing the correct conclusions. Accreditation occurs at a key point in the process to solve a given problem. At this point, the person responsible for accepting the solution determines the model or simulation is sufficient for its intended use. Accreditation is a decision to use a model or simulation for a specific application (i.e., project or program). The decision is supported by as much information as is necessary to be credible. According to DoD Directive 5000.59, accreditation is "the official certification that a model or simulation is acceptable for a specific purpose." Accreditation, then, must be associated with a specific purpose or application.

This section describes the process leading up to and supporting accreditation. This process is shown in Figure 5.0-1. Note that the accreditation process is conducted concurrently with the V&V process. For EADTB, V&V is a part of the accreditation process.

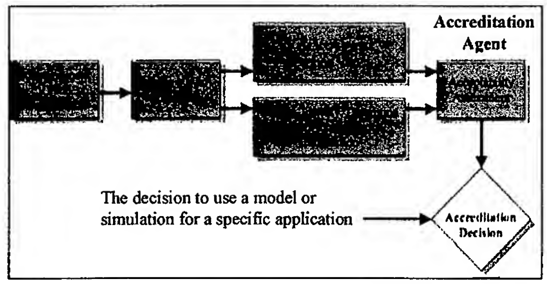


FIGURE 7.0-1 THE ACCREDITATION PROCESS

7.1 Accreditation Requirements

The accreditation process begins with the determination of accreditation requirements. These requirements include the V&V requirements as well as other M&S characteristics needed and constraints based on application limitations. The V&V requirements are determined by the application sponsor. These key functions are prioritized in order of importance to the application. The V&V status of each of the key functions is then determined. The V&V status reflects whether V&V has been performed on this M&S function, the quality of the V&V performed, and the actual V&V findings. Other accreditation requirements include M&S characteristics that can affect the decision for the model's or simulation's approval and use. These factors include (a) model or simulation development and use history, (b) operational environment requirements, (c) configuration management status, (d) documentation status, and (e) other known capabilities and limitations of the model or simulation and supporting data bases.

7.2 Accreditation Planning

The application-specific accreditation requirements are satisfied based on the accreditation plan. The plan contains the list of requirements to be satisfied, the method of meeting each requirement, the agent responsible for each requirement, the overall resources needed, and the schedule for satisfying the requirements. A major subset of the accreditation plan is the V&V plan. For EADTB, this is a separate plan because it is the major work to be accomplished. Each requirement is examined, and the optimum method of requirement satisfaction is selected. The optimum is based on a trade-off of cost,

resources, and time to complete. Each requirement satisfaction method then is grouped appropriately and integrated to give an overall approach to meeting the requirements. Requirements that drive the cost, resources, or schedule are re-examined to find more efficient ways of satisfying them. If no alternative can be found for a requirement that is excessively costly or time consuming, it is reconsidered. Based on its priority, the requirement can be accepted as is, reformulated to make it easier to accomplish, or eliminated. Once the methods for all requirements are accepted, an integrated resource list and schedule is developed. If the V&V requirements are to be accomplished through a separate plan, they are documented separately. The approach to meeting all requirements is documented in the accreditation plan.

7.3 Accreditation Plan Execution

Once the accreditation plan has been approved, satisfaction of the requirements begins. The non-V&V requirements are met using the methods specified in the accreditation plan. These methods usually involve identifying sources of and collecting information, which should be documented. If execution of the accreditation plan is long or detailed, interim reports and reviews of progress may be appropriate.

7.4 Acceptability Assessment

The acceptability assessment reviews all accreditation information, both V&V and non-V& V, and develops a list of capability voids, weaknesses, and mismatches of model or simulation functions and characteristics versus application acceptability criteria. If modifications to the model or its data base are necessary to fill voids or correct weaknesses, approaches to these modifications along with the resources required and a schedule are developed and documented. If the voids or weaknesses can be avoided by limiting the uses of specific models or algorithms, these limitations are documented. If there is a potential, yet undetermined weakness because of a lack of V&V, the additional V&V needed to determine if the weakness exists is estimated in terms of resources and time. The capability voids and weaknesses are analyzed together to develop an overall recommendation for EADTB use, EADTB use with limitations, EADTB modifications, additional V&V, or EADTB rejection. The results of the acceptability assessment and the recommendation with its rationale are documented in the acceptability assessment report and briefed to the accreditation authority.

Accreditation Authority

The accreditation authority then has the responsibility to review the results of the acceptability assessment and, based on that information as well as other factors, make a decision. Among the other factors the accreditation authority may consider are a projected program schedule slip (for an acquisition program) or an anticipated budget decrease (or increase). The accreditation authority may ask the acceptability assessment team to develop additional information or different approaches to fill voids or eliminate weaknesses in a model's or simulation's capabilities before a decision is made. The decision can be one or a combination of the following:

a. Use the EADTB as it is for the application.
b. Use the EADTB with limitations in that use.
c. Modify the EADTB before use.
d. Perform additional V&V.
e. Do not use the EADTB for this application. Alternatives C through E incur additional costs and cause schedule changes. Alternative E is the most severe because it causes the process to begin again at developing the M&S.

8.0 VV&A Documentation

A crucial step in the EADTB VV&A process is the documentation of all V&V findings. These documents are used as the primary source documents for accreditation. All V&V documentation is assembled in the VV&A library at the IV&V contractor's facility. These documents include the general EADTB VV&A plan, VV&A plans specific to particular tests or studies, IV&V analysis reports covering analysis of critical algorithms and processes within EADTB, IV&V briefings, results of exercises and studies, formal VV&A reports associated with particular studies, the EADTB SSR validation plans, certification letters from the project offices and system project offices (SPOs), all user documentation and all developer documentation. Access to information in the

VV&A library is controlled by the Testbed Product Office (TPO).

A VV&A database has been created and maintained and is used to track the progress of the activities performed related to testing system requirements. The database provides traceability to the VV&A testing approach. The database contains a list of the requirements tested and a summary of the testing activities performed. Critical activities for each requirement are identified, performed, and documented in the database. Standard results reports are generated from the database and are added to a test report. The database was created using Microsoft Access.

All VV&A documentation is controlled under standard configuration management procedures and is updated as needed, to parallel the on-going EADTB development.

9.0 Conclusions

The result of a sound VV&A process as applied to EADTB provides confidence in the use of the simulation. Risk is reduced in decision-making based on results of the simulation and usability is increased for future applications of EADTB. Costs are contained by performing comprehensive VV&A and most importantly DOD policy requirements are met while preserving technical merit.

10.0 Applicable References and Documents

The following publications were used in preparing this document:

- Department of the Army. Verification, Validation, and Accreditation of Army Models and Simulations. 15 October 1993. Pamphlet 5-11. Washington, D.C.
- Department of Defense. Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide. November 1996. Office of the Director of Defense Research and Engineering Defense Modeling and Simulation Office.
- Department of Defense. DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A). 29 April 1996. DoD Instruction Number 5000.61.
- Department of Defense. Report of the Verification, Validation, and Certification (VV&C) Tiger Team. 4 June 1998. DoD Directive Number 5000.59.
- Department of the Navy. Department of the Navy Modeling and Simulation Program. 18 October 1994. SECNAV Instruction 5200.38. Washington, D.C.